Collider - Accelerator Department
BROOKHAVEN NATIONAL LABORATORY
Brookhaven Science Associates
Upton, New York 11973

Specification No. CAD-1163

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SPECIFICATION

FOR

EBIS COLLECTOR POWER SUPPLY

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1.0 GENERAL

1.1 This specification describes in detail the design, construction, testing and performance of rectifier modules. The rectifier modules shall be used for the conversion of three-phase, 60 Hz power to six pulse output DC power which will be connected to a remotely located RF power amplifier using high voltage cable for the AGS RF system at Brookhaven National Laboratory.

1.2 Each rectifier module shall be three phase, full wave, six pulse DC output power supply. The module is comprised of a three phase full wave, solid state silicon, diode bridge, LC filter and crowbar protection system. Each module shall be enclosed in an all metal enclosure and shall be forced air cooled. **The transformers for each module will be supplied separately and are not covered in this specification. The transformers will be located outside of the rectifier modules. Reference shall be made to transformer data for module design purposes only.** (See section 7.0).

1.3 The rectifier modules supplied under this specification shall be in strict accordance with the latest standards, publications and definitions of the American National Standards Institute (ANSI), the Institute of Electrical and Electronic Engineers (IEEE), and the National Electrical Manufacturers Association (NEMA), where applicable. The rectifier modules shall be manufactured in accordance with the best of existing techniques and recognized good engineering practices. In all cases reference shall be made to recommended procedures of the standards of the above organizations, and also the National Electric Safety Code and the National Electric Code. Where this specification differs from the above standards and procedures, this specification shall apply.

1.4 Materials used in the manufacture of the rectifier modules shall be of the kind, composition, and physical properties best adapted to their various purposes in accordance with good engineering practice. Tolerances, fits and techniques used in the manufacturing of finished products shall conform to the best modern shop practices. All like parts shall be interchangeable between units wherever possible.

1.5 Vendor qualification shall be based, in part, on the vendor's previous technical experience in the field of High Voltage rectifier construction. Brookhaven reserves the right to inspect the vendors facilities prior to the awarding of a contract.

2.0 SUBSTITUTIONS

2.1 The specification for various portions of the work describe certain special materials, processes and products of manufacture which will be required unless equal construction is specifically approved in writing by the cognizant BNL engineer.

Should the vendor propose to furnish other "equal" materials, processes or products, either in substitution for or as an alternate to those specified, he shall so state in his proposal and shall submit full details. The cognizant BNL engineer's decision as to the equality of any material, process, and product to those specified shall be final.

Approval by the cognizant engineer shall not relieve the vendor from his responsibility concerning such work or affect the guarantee covering all parts of the work.

2.2 Included in this specification are descriptions of components, materials, accessories, guarantees of specified performance and methods of ensuring quality. Since this application demands that the rectifier modules be manufactured to the highest standards of reliability and performance, we have specified certain of the major components, however, prospective vendors are encouraged to offer alternative products which will provide equal or better performance and reliability.

3.0 SCOPE OF WORK

3.1 The vendor shall supply all labor, materials and equipment necessary to design, manufacture and test the rectifier modules described in this specification. The vendor shall also provide all labor and resources to produce detailed up to date documentation of the rectifier modules as built. It shall be the responsibility of the vendor to insure that the rectifier modules meet the requirements of this specification in a reliable and conservative fashion. The equipment shall be designed to have an expected service life in excess of twenty years. No deviation from this specification is allowed except by written permission from the cognizant Brookhaven engineer.

3.2 The vendor shall prepare and load the rectifier modules for shipment and deliver them undamaged to the F.O.B. destination: Brookhaven National Laboratory, Upton, New York 11973. The vendor is responsible for on time delivery of the rectifier modules, and is liable for all damage incurred in shipment.

3.3 The vendor will be held responsible for the design, construction and testing of these rectifier modules. However, the vendor will not be held responsible for the installation and system testing at Brookhaven.

3.4 The Brookhaven cognizant engineer shall have final approval as to the determination of design parameters, operational margins, specification interpretation, control, protection and testing. Differences between the vendor's proposal and the standards or Brookhaven's requirements shall be resolved by the cognizant engineer's determination. Vendors shall obtain written approval from the Brookhaven cognizant engineer before proceeding with the final design and fabrication. No deviation from the specification will be allowed unless specifically authorized by Brookhaven in writing.

4.0 SUBMITTALS BY VENDOR

4.1 The vendor shall submit a proposal that gives a **PARAGRAPH by PARAGRAPH** response as to how he intends to comply with this specification. Any exceptions which the vendor may take to the specification shall be clearly noted in the proposal. The vendor shall state in the proposal that he is in full compliance with all aspects of this specifications which are not noted as exceptions.

4.2 The Vendor shall fill out the attached form entitled "Vendor Data Sheet" and return it with his proposal. All exceptions on this form shall also appear in the exceptions section as per section 4.1.

4.3 The proposal shall include a list of assembled rectifier modules with similar ratings and construction which the vendor has produced and shipped. The list shall include the performance data for these rectifiers, the purchaser's name and shipping date.

4.4 The vendor shall describe in his proposal the testing capabilities of his facility and the electrical capacity of the test site, with a view towards the testing of these modules.

4.5 Three sets of preliminary outline drawings showing the rectifier module overall dimensions, all component placement, preliminary schematics and a preliminary manufacturing schedule shall accompany the proposal.

4.6 The vendor shall supply the BNL engineer with a preliminary acceptance test procedure two weeks prior to the final design review meeting. Three (3) weeks prior to first article testing, the vendor shall submit for BNL's review and approval, a copy of the final test procedure.

4.7 The vendor shall specify in detail the guarantee period and its provisions in his proposal. (See Section 20.3).

5.0 DESIGN REVIEWS

5.1 Prior to awarding a contract under this specification a pre-award meeting shall be held at the vendor's facility. At this time a preliminary review of the submitted design will be held and the capability of the vendor to produce the rectifier modules in a timely manner will be evaluated.

5.2 A design review shall be held eight (8) weeks after receipt of order and prior to commencement of fabrication. Three (3) sets of all electrical schematic drawings, mechanical assembly drawings, a formal manufacturing schedule and a complete parts list shall be submitted to Brookhaven at least two (2) weeks prior to the design review date. Agreement shall be reached during the design review not only on the drawings and material submitted, but also on the vendor's manufacturing plan, test procedure and schedule. After BNL approval, the vendor shall promptly begin the assembly of the first article (prototype) rectifier module.

6.0 PERFORMANCE AND DESIGN CHARACTERISTICS

6.1 The vendor shall supply equipment which, when installed by Brookhaven, will guarantee to meet or exceed the performance criteria specified in the following sections and elsewhere in this specification. Even though the load current is described as pulsed, the ratings of all the components utilized in this equipment shall be interpreted to be **continuous duty (24 hours/day).**

6.2 The rectifier modules shall be supplied as completely assembled units in all metal enclosures together with the crowbar system, protection, control and monitoring circuitry. A suggested simplified schematic diagram is shown in Fig. 1.

6.3 The following outlines the output voltage and current characteristics of each rectifier module. The specification defines the total system including the transformer described in section 7.0, but which are not part of this solicitation. The vendor shall take the transformer data into account when calculating the performance specified.

6.3.1 Output voltage shall be adjustable from 9KVDC to 13KVDC via a no-load tap switch located in the primary of the **external** rectifier transformer, see section 7.0 for transformer data.

Tap 1 .....13KVDC @ 30 Amps
Tap 2 .....12KVDC @ 30 Amps
Tap 3 .....10.5KVDC @ 30 Amps
Tap 4 .....9KVDC @ 30 Amps

6.3.2 The output voltage regulation shall not exceed ten (10) percent over the load current range of 5 amperes to 30 amperes without preloading of the rectifier and excluding any voltage drop in the series resistor in the positive output lead, (isolating resistor) see section 16.5.

6.3.3 The output voltage ripple shall not exceed 0.7% peak-to-peak of the DC output voltage for all voltage settings from 9 KVDC to 13 KVDC up to 30 amperes load current.

6.3.4 The amplitude of the transient oscillation from the original to the final value of the output voltage shall not exceed 10% with a step increase or decrease in load current of 30 amperes, and at any output voltage.

6.4 The surge ratings of the individual diodes used and the internal design of the module shall be such that a module can repeatedly, **(five faults per minute maximum),** handle the full expected fault current of the system until the external protection devices can safely shut the system down. The maximum fault current time period shall be for eight (8) power line cycles at 60 Hz, see section 10.6.

6.5 Each rectifier module will be controlled and protected by medium voltage type circuit breakers connected at the primary side of the rectifier transformer. The rectifier AC input shall employ transient protection devices to limit the switching transients generated by the turning on and off of the input circuit breaker.

6.6 All semiconductor components utilized in the rectifier modules shall be available and be interchangeable with those from several manufacturers (or equivalent units from second source) and shall be utilized in other applications that assure their future availability for a period exceeding five (5) years.

7.0 TRANSFORMER

7.1 **The transformers shall not be provided by the vendor. Reference shall be made to transformer data for rectifier module design purposes only.**

7.2 The following transformer data is for each rectifier module.

7.2.1 Rating, KVA (OA/FA) 417 KVA/480KVA

7.2.2 Winding configuration ..... De1ta-Wye (with electrostatic shield)

7.2.3 Primary Voltage, volts ..... 13.8KVrms, 60Hz, (+ 10% max, -5 % min) 3 phase

7.2.4 Secondary Voltage, volts, ± 3%.....Values obtained with primary taps and 13.8 KV supply voltage

Primary Tap 1 (100%) @ 25A.....9630 Vrms
Primary Tap 2 (92.3%) @ 25A.....8889 Vrms
Primary Tap 3 (80.8%) @ 25A.....7778 Vrms
Primary Tap 4 (69.2%) @ 25A.....6667 Vrms

7.2.5 Secondary Current, max, line amperes .....25 amp.

7.2.6 Secondary Voltage unbalance (max) .....2% of nominal each winding, all taps. secondary volts

7.2.7 Impedance, Tap 1..... 6%, (± 7.5%)

7.2.8 Duty Cycle .....Continuous, crowbar service

7.2.9 Fau1t duration time(max) 8 cyc1es

7.2.11 Available Short circuit current.....15 KA (to primary terminals)

7.2.12 Efficiency..... 98%

7.2.13 High potential test voltage .....34 KV rms

8.0 RECTIFIERS

8.1 The peak inverse catalog voltage rating of each rectifier assembly comprising a leg of the full wave bridge shall be at least three (3) times the maximum applied voltage seen by a leg.

8.2 The ON and OFF or other induced switching transients shall be limited to 50% of the catalog inverse voltage ratings. Appropriate overvoltage limiting devices shall be placed at the three AC input lines of the rectifier bridge.

8.3 The vendor shall minimize the number of rectifier cells employed in series to meet the voltage requirements. The individual rectifier cells employed in series shall have circuitry and components connected across them to assure proper equalization or sharing of the applied voltages, both forward and inverse to within ± 10%. Equalization by external transient suppression circuitry and components shall apply both statically and dynamically.

8.4 The average current rating of all silicon rectifiers shall be at least one and a half (1.5) times their expected average operating current. The peak surge current rating of the rectifiers shall be at least two and a half (2.5) times the anticipated (peak and rms) discharge current during a power supply crowbar .

8.5 The rectifiers shall be forced air cooled. The units shall be mounted on heat sinks according to the recommendations of the semiconductor manufacturer. The maximum junction temperature shall be limited to **100 °C** under worst case conditions with a maximum intake air temperature of **40 °C**.

8.6 The rectifier cells shall be mounted with consideration for replacement and maintenance accessibility, the vendors preliminary drawings shall show their position in the power supply.

9.0 FILTER

9.1 The output voltage ripple shall not exceed 0.7% peak-to-peak of the dc output voltage for all voltage tap settings when fed from a transformer as described in section 7.0.

9.2 All capacitors used in the filter circuit shall be capable of energy storage and discharge. The capacitor bank shall include enough capacitors so that the rms current of each capacitor is not exceeded. Current limiting resistors connected in series with each capacitor may be used to limit the discharge current during the firing of the crowbar. Bleeder resistors shall be installed across each capacitor to ensure proper discharge of the capacitor when the rectifier modules are turned off. The capacitors selected must be able to withstand repeated discharges by the crowbar circuit, see section 10.3. The capacitors shall be rated to handle all applied voltages and shall be protected from the application of high reverse voltage.

9.3 MOVs shall be installed across all filter inductors to prevent destructive voltage from being induced in the inductor during transient and fault conditions. The MOVs shall be sized to withstand repeated faults due to the firing of the crowbar circuit. The inductors and MOVs must be capable of meeting the high potential tests in section 17.5.4.

10.0 CROWBAR

10.1 The rectifier module shall have a fast acting crowbar to protect the output tubes in the RF power, amplifier load. The crowbar protection shall be designed to discharge all the rectifier module stored energy devices after a fault current (typically a tube arc) is sensed.

10.2 The vendor shall provide the crowbar ignitron, ignitron pulse transformer, heaters and heater regulator circuitry. The crowbar trigger circuit will be supplied by BNL and shall be housed in a Nim Crate located within the crowbar trigger EMI/RFI compartment, see section 14.4. The crowbar trigger circuit wiring shall be supplied by the vendor. Details of the BNL trigger circuit hookup will be provided prior to the final design review.

10.3 The crowbar ignitron tube shall have a maximum voltage rating of two (2) times the maximum applied voltage. The ignitron peak surge current rating shall be at least two and one half (2.5) times the anticipated maximum discharge current and must be able to withstand this current for a maximum of eight (8) cycles of 60 Hz without damage to the crowbar or load. This is repeated up to five times within one minute. The tube selection shall be approved by BNL.

10.4 The ignitron pulse trigger transformer shall have a dual secondary winding, one winding shall be connected to the crowbar ignitron and the second winding shall be wired to a MHV /BNC type connector, located in the module control compartment, for triggering of external crowbar devices. The primary winding (Vin) shall be rated for 1KV (max) with an input impedance of 50 ohms. The input pulse width will be 5 to 10 microseconds. Secondary winding No. 1 shall provide an output voltage pulse of 3KV and shall be used to trigger the ignitron tube. Secondary No. 2 shall provide an output pulse of 24V of approximately 1ms rise time and 5ms width into 50 ohm for triggering an external crowbar device. Alternate means of delivering this trigger pulse will be considered.

10.5 The crowbar protection test criteria for the rectifier module is to short the DC output terminals through a Ross type relay and a six (6) inch length of #30 AWG copper wire, with the wire remaining intact after the relay closure.

10.6 The crowbar test circuit shall be supplied by the vendor and be a part of the rectifier module. The crowbar test circuit shall consist of a Ross relay and a six (6) inch length of #30 AWG copper wire connected in series across the rectifier module output terminals. The crowbar test push button will close the relay simulating a load arc. The expected frequency of operational testing is a maximum of one test per day at a maximum rate of five times in one minute. The vendor shall provide a monitor circuit as well as visual observation to verify the condition of the #30 AWG wire. Should the wire be damaged, a crowbar fault shall be detected by the PLC and will shut down the rectifier module, (standby), and shall prevent the rectifier module from being turned on. The crowbar fault circuit shall be energized if any of the crowbar device power supplies fail. The crowbar fault interlock shall be resettable locally only.

11.0 PROTECTION DEVICES AND CONTROL CIRCUITS

11.1 The following devices, (sections 11.1 thru 11.14), shall be incorporated in the rectifier modules and shall be used to interlock the modules to internal and external control devices. All of the interlocks and controls of each module shall be connected to a programmable logic controller in the module control compartment. Some interlocks and control devices shall be wired directly to terminal strips and to external protection circ.uits as well as the programmable logic controller, these interlock circuits are defined under each device section. All control, interlock devices and circuits must meet the high potential tests of section 17.5.4.

11.2 The control voltage for the rectifier module shall be 24 Volts DC. The input voltage for the 24 Volt DC power supply shall be 120 Volts AC externally supplied. The 24 Volt power supply shall be provided by the vendor. The 120 Volt AC power shall be housed in the module control compartment and shall be grouped together in one location and covered with a safety barrier and warning signs. A two pole 120 Volt circuit breaker shall be provided by the vendor and the handle of the control circuit breaker shall be accessible without removing the 120 Volt AC safety barrier.

11.3 A suitable EMI/RFI line filter shall be provided for 120 Volt AC line noise filtering. The filter shall be properly sized to match the maximum voltage and current rating of the control circuit.

11.4 A high current relay or contactor shall be provided which will be used to turn the 120 VAC control power on and off, **(Standby relay)**. The relay shall be an Allen-Bradley type 700DC-P400Z24 or approved equal with a coil voltage of 24 VDC and 4 poles. The coil shall be controlled by the output module of the PLC and shall have a MOV connected across the coil to limit the back EMF to the PLC module. When the relay is deenergized all 120 VAC power shall be off except to the PLC and the PLC 24 VDC control power supply. An auxiliary contact from the standby relay shall be wired to an input module of the PLC for standby status.

11.5 The vendor shall provide a **master interlock relay** and it shall be connected to the PLC output module. The relay shall be an Allen-Bradley type 700DC-P400Z24 or approved equal with a coil voltage of 24 VDC and 4 poles. The coil shall have a MOV connected across it to limit the reverse EMF the PLC output module will receive. The relay shall be located in the module control compartment.

11.6 The vendor shall provide the following programmable logic controller devices in each rectifier module. The Allen-Bradley PLC-5 devices specified are part of a standard product line used at BNL for all rectifier devices. The logic programming of the PLC will be provided by BNL and will be based on the final wiring schematic approval at the design review. The program will be supplied four (4) weeks after the final design approval. The PLC Ladder Logic control program for the control and protection of the rectifier module will be provided by BNL on a PLC-5/12 EEPROM module.

11.6.1 One each, Universal I/O chassis, No. 1771-A2B.
11.6.2 One each, 120 Volt power supply module, No. 1771-P4S.
11.6.3 One each, PLC-5/12 processor module, No. 1785-LT3.
11.6.4 One each, 8K EEPROM memory module, No. 1785-MJ.
11.6.5 Three each, DC (10-30V) input module, No. 1771-IBD.
11.6.6 One each, DC (10-60V) output module, No. 1771-0BD.
11.6.7 One each, Analog input module, No. 1771-IFE.

11.7 Over temperature protection of each rectifier cell will be required. The over temperature detection device shall be a thermostat type switch (or equal) with contacts that are electrically isolated from the heatsink, and must be capable of meeting the high potential test in section 17.5.4. The thermostats shall be automatic reset type with normally closed contacts suitable for operation on a 24 Volt DC system. The trip point of the thermostat is to be set to protect the rectifier cells from exceeding the manufacturer's recommended maximum safe operating case temperature for the maximum junction temperature given in section 8.5. All the over temperature devices shall be wired individually to the PLC input module for interlock control and alarm monitoring.

11.8 Air flow switches shall be provided by the vendor for each cooling fan or blower. Each air flow switch shall drop out with a 50 percent reduction of air flow. The air flow switch shall have a normally open contact that closes when the air flow is normal. All the contacts shall be suitable for operation on a 24 Volt DC system and shall be wired individually to the PLC input module for interlock control and alarm monitoring.

11.9 Interlock microswitches shall be mounted on all hinged doors of the rectifier module that lead to high power AC and DC circuitry. The switches used shall be similar to the Micro-Switch type V-3. The rectifier module control compartment door shall not be interlocked. The door switches shall be **wired directly** in series with the master interlock relay coil. The door interlock switches shall also provide contacts for status information to the PLC for other interlock control and alarm indication. The contacts shall be suitable for 24 Volt DC operation.

11.10 The rectifier module shall have a DC over current sensing device which has an adjustable trip setting from 10 percent to 110 percent of rated DC output current. The over current device shall use the module's internal DC transductor, DCCT, (see section 12.2). The DC over current device shall be mounted in the rectifier module control compartment. The DC over current device alarm contacts shall be **wired directly** in series with the master interlock relay coil. It shall also provide a second normally closed contact to be wired to a PLC input module for interlock control and alarm indication. The contacts shall be suitable for 24 Volt DC operation.

11.11 Cubicle over temperature shall be provided by the vendor. The device used shall be adjustable and shall be wired to the PLC input module for interlock control and alarm indication. The contacts shall be normally closed and shall open when an over temperature is detected. The contacts shall be suitable for 24 volt DC operation. The

over temperature trip adjustments shall be located within the rectifier modules control compartment.

11.12 The vendor shall install an automatic shorting device, (similar to the Ross relay), across the output terminals of the rectifier module. When an interlocked door is opened the shorting device shall short the output of the rectifier module. The device shall be wired to the PLC output module. The shorting device shall be wired in a fail safe manner, when the circuit is deenergized the shorting device will drop down by gravity and short out the rectifier module. The shorting device coil shall be rated for 24 VDC and shall have an MOV connected across it to reduce the reverse EMF the PLC output module will receive.

11.13 The vendor shall provide a manually operated shorting device that will short out the rectifier module when the high voltage AC and DC compartment doors are unlocked or opened.

11.14 The vendor shall provide the following control switches ~d status indicators. All push button and knob lever operator switches shall be NEMA type 4/13, similar to Allen-Bradly type 800T-H or approved equal. Status indicator lights shall be similar to the Allen-Bradly type 800T-QL24R, all indicator lights shall be LED type and shall be rated for 24 VDC.

11.14.1 OFF PUSH BUTTON:

Momentary, normally closed contact, 24VDC, green operator. Switch shall be wired to a PLC input module. The switch shall be used to deenergize auxiliary equipment, fans, filaments, heaters and power supplies. The PLC and the PLC 24VDC control power supply shall remain energized.

11.14.2 STANDBY/RESET PUSH BUTTON:

Momentary, normally open contact, 24VDC, yellow operator. Switch shall be wired to a PLC input module. The switch shall be used to energize all auxiliary equipment, fans, filaments, heaters, power supplies and start any time delay circuits. If the rectifier module is ON when the standby switch is depressed then the rectifier main circuit breaker will be deenergized and the rectifier will be returned to a standby/ ready state.

11.14.3 ON PUSH BUTTON:

Momentary, normally open contact, 24VDC, red operator. Switch shall be wired to a PLC input module. The switch shall be used to energize the main external circuit breaker which supplies power for the high voltage DC output.

11.14.4 LOCAL/REMOTE SWITCH:

Two position knob level switch, one N/O and one N/C contact, 24VDC, black operator handle. Switch shall be wired to a PLC input module. The switch shall be used to transfer the control functions between the local and remote devices. Remote control of the rectifier shall be done through the PLC network, (remote I/O).

11.14.5 CRASH PUSH BUTTON:

Momentary, normally closed contact, 24VDC, large red mushroom push button unit with latch. The switch shall turn off the high voltage and prevent the rectifier high voltage from being turned back on. To reenable the high voltage the crash switch will have to be reset locally. The switch shall be similar to Cutler-Hammer No. CH-10250ED952 or approved equal.

11.14.6 CROWBAR TEST PUSH BUTTON:

Momentary, normally open contact, 24VDC, black operator. The switch shall be wired to a PLC input module. The switch shall be used to test the crowbar system.

11.14.7 SERVICE LIGHT SWITCH:

Two position (on/off) knob level switch, two pole, normally open contacts, 120 VAC, black operator handle.

11.14.8 OFF INDICATOR LIGHT:

24VDC, LED indicator, green lens. The light shall be wired to a PLC output module.

11.14.9 STANDBY INDICATOR LIGHT:

24VDC, LED indicator, amber lens. The light shall be wired to a PLC output module.

11.14.10 READY INDICATOR LIGHT:

24VDC, LED indicator, blue lens. The light shall be wired to a PLC output module.

11.14.11 ON INDICATOR LIGHT:

24VDC, LED indicator, red lens. The light shall be wired to a PLC output module.

11.14.12 FAULT INDICATOR LIGHT:

24VDC, LED indicator, white lens. The light shall be wired to a PLC output module.

12.0 INSTRUMENTATION

12.1 The vendor shall provide an isolated DC potential transformer (DCPT) for local and remote monitoring of the total DC output voltage of each rectifier module. The DCPT shall have an accuracy of ± 1%, a bandwidth greater than 5 KHz and must meet the high potential test requirements in section 17.5.4. The DCPT shall be the Liaisons Electroniques LEM Module LV200-AW/SP1 or approved equal, the volts/volt scale shall be 0.5 Volts/KV output. The output of the DCPT shall be wired to the customer terminal strip in the control compartment, to an isolated BNC connector mounted on the front of the rectifier module and to an input of the analog input module of the PLC.

12.2 An isolated current transductor (DCCT) shall be provided by the vendor for local and remote monitoring of the module output DC current. The DCCT shall have an accuracy of ± 1%, a bandwidth greater than 5 KHz and must meet the high potential test requirements of section 17.5.4. The DCCT shall be the Liaisons Electroniques LEM Module LT100-S or approved equal, the Volt/Amp scale shall be 0.1 Volt/Amp output. The output of the DCCT shall be wired to the customer terminal strip in the control compartment, to an isolated BNC connector mounted on the front of the rectifier module and to an input of the analog input module of the PLC. The DCCT shall provide an output for the DC over current device defined in section 11.10.

12.3 The vendor shall provide a crowbar trigger detector current transformer (CT). The CT shall be installed in the positive output bus. The CT shall be a Pearson Electronics, Inc. wide band current transformer, model No. 110. The CT mounting must meet the high potential test requirements of section 17.5.4.

12.4 An analog DC voltmeter shall be provided by the vendor. The voltmeter shall be used to monitor the rectifier modules output voltage. The meter shall read 0 to 20 KVDC and have a full scale accuracy of ± 3 % . The voltmeter shall be operated off the isolated DC potential transformer (DCPT), see section 12.1.

12.5 An analog DC ammeter shall be provided by the vendor. The ammeter shall be used to monitor the rectifier modules output current. The meter shall read 0 to 30 ADC and have a full scale accuracy of ± 3%. The ammeter shall be operated off the isolated DC current transductor, (DCCT), see section 12.2.

13.0 COOLING

13.1 The rectifier module shall be forced air cooled. The intake air shall enter the cabinet through removable dust filters located at the front of the cabinet and exit through the top of the cabinet. The air filters shall be removable from the outside of the rectifier

so that the filters can be changed without turning the rectifier off. Expanded metal shall be installed behind the air filters to prevent access into the rectifier whenever the air filters are removed.

13.2 The inlet cooling air temperature will be 40 °C maximum, 0 °C minimum with a maximum relative humidity of 99%.

14.0 MECHANICAL CONSIDERATIONS

This supply is a replacement for existion units. Figure 2 in section 23.0 shows the maximum dimensions of the cabinet, and the approximate location of the connectors and cable access areas. Before the order is placed, a list of connectors and pin numbers for the functions of those connectors shall be furnished to prospective vendor. This supply must be supplied with those connectors and that pin-out.

14.1 The rectifier modules shall be constructed in an all-metal cabinet which shall be in accordance with NEMA standard for Indoor Power Switchgear as per publication No. SG5, latest edition.

14.2 The rectifier module cabinet shall be partitioned into a minimum of three (3) compartments. For safety purposes, personnel access between compartments shall not be permitted. The three compartments are:

14.2.1 Module control compartment.

14.2.2 Crowbar trigger compartment.

14.2.3 High voltage AC and DC rectifier compartment.

14.3 The module control compartment shall be used to enclose all of the module controls, programmable logic controller, over current devices, relays, protection, interlock, system monitoring and status indications. This compartment shall be physically isolated from the other compartments and shall be of all metal construction for electrical shielding. This compartment shall not have any voltage greater than 120 Volts AC. All 120 Volt AC voltages shall be barriered. The 120 Volt AC input control power shall enter the module control compartment via a conduit fitting at the top of the cabinet and shall be terminated on a covered terminal strip which connects directly to the control power circuit breaker, see section 11.2,3. This compartment shall have an unlocked door and shall not be interlocked. A clear Lexan panel shall be provided on the door for viewing the PLC indicator lights.

14.4 The crowbar trigger compartment shall be located in the bottom of the module control compartment. The crowbar trigger compartment shall be completely shielded for EMI/RFI. The compartment shall be recessed within the module control compartment and shall have a separate door for EMI/RFI shielding. The module control compartment door shall close over the crowbar trigger compartment door. The crowbar trigger compartment dimensions shall be 16 inch high by 24

inch deep by 24 inch wide. Mounting angles shall be provided with standard drilling to enable 19 inch equipment to be mounted in it.

14.5 The main 10KV AC input shall be through the top left rear of the module. An AC access door shall be provided on the front of the rectifier module for cable hookup and servicing. The door shall be electrically interlocked with micro switches, see section 11.9, and mechanically locked. The vendor shall provide the mounting for a Kirk type "F" lock, which will be purchased and installed by Brookhaven. The access door shall have a viewing window. The window shall be safety glass or expanded metal with a Lexan panel.

14.6 The DC output shall be through the top right rear of the module. An access door shall be provided on the front of the rectifier module for cable hookup and servicing. The door shall be electrically interlocked with micro switches, see section 11.9, and mechanically locked. The vendor shall provide the mounting for a Kirk type "F" lock, BNL will purchase and install the Kirk locks at Brookhaven. The access door shall have a viewing window. The window shall be safety glass or expanded metal with a Lexan panel.

14.7 Rear access to the rectifier enclosure shall not be required. Left and right side access shall be provided through bolted side panels.

14.8 The module cabinet shall have lifting eyes located on the top side of the unit which are so connected to the frame that frequent handling by overhead crane is permissible. The frame shall be made sufficiently rigid so that frequent lifting and relocation shall not cause deformation or door misalignment. All bolted connections located in blind locations shall have captive hardware.

The vendor shall provide engineering calculations that show that the cabinet frame and lifting eye mounting points have been designed to handle the full weight of the power supply assemblies with a 3 to 1 design safety factor. Any lifting hardware (lifting eyes for example) provided must sized to handle the intended load at its lift point. The hardware item must be marked with the hardware manufacturer's name and its part number.

14.9 The base of the rectifier module shall be mounted on four (4) inch channel or I-beam to keep the unit off the floor and to allow the unit to be moved with a fork lift. The dimensions of the rectifier module shall be no greater than three (3) feet deep, six (6) feet wide and six (6) feet high.

14.10 A copper ground pad shall be welded to the frame to provide for an external ground connection. The ground pad shall have two (2) ½-13 inch tapped bolt holes spaced 1.75 inches apart. The steel as well as the copper shall be tapped for ½-13 thread. The ground pad location shall be at the top left rear of the unit.

14.11 The vendor shall provide a discharge pole (grounding stick) permanently connected to the rectifier module frame ground. The discharge pole shall be located outside the AC and DC compartment doors. The ground lead on the pole shall be of

sufficient wire size; bare or braid to handle the discharge currents encountered when the energy storage devices are discharged. The ground lead shall be enclosed in a clear, flexible insulating sleeve such that the condition of the ground lead can be monitored. The insulating sleeve shall be required to protect the personnel using it from injury when the discharge pole is used to discharge the rectifier module.

14.12 The finish of the cabinet shall consist of degreasing the unit followed by a coat of rustproofing paint and two (2) coats of synthetic resin enamel, color "red", Federal stock number 595-21105 for the exterior, and "white", Federal stock number 595A-27886 for the interior or approved equal.

14.13 The noise level three (3) feet away from the rectifier module from all sources including cooling fans, shall be less then 70dB when the unit is on and operating.

14.14 No exterior surface of the rectifier module cabinet shall exceed a temperature of 50 degrees C when the module is operating at maximum output rating.

14.15 Guarded interior incandescent lights shall be provided in each compartment for servicing the rectifier module. The 120 VAC for the lights shall be controlled by a service switch located on the front door. See Section 11.14.7. The service power shall be supplied through fuses and shall not be supplied by the control power circuit breaker, this will allow servicing the unit with control power circuit breaker off.

15.0 NAME PLATE

15.1 The vendor shall supply a stainless steel name plate for each rectifier module giving all standard information, including the following:

15.1.1 Manufacturer's name and address.
15.1.2 Type, serial number and date of manufacture.
15.1.3 Input voltage and current rating.
15.1.4 Output voltage and current rating for each tap.
15.1.5 KW rating.
15.1.6 Total weight.
15.1.7 Allowable temperature rise.
15.1.8 Maximum inlet air temperature.

16.0 HEAT SINKS, BUS BAR, CABLE AND TERMINALS.

16.1 Individual diode heat sinks and clamps shall clamp the semiconductor devices according to the diode manufacturer's recommended clamping pressure. An approved thermal joint compound shall be utilized. The heat sinks shall also provide convenient connections as well as the heat exchange surface areas to adequately cool the devices.

16.2 All interconnections and buswork within the rectifier module shall consist of copper bus or cable of adequate size and voltage insulation to limit the temperature on the bus or cable to 60 °C or less. Proper joining practices, bolting schedules, and hardware shall be followed for the copper bus and cable, (References: Alcoa Aluminum Bus Conductor Handbook). All blind locations bolted joints shall have captive hardware. An adequate number of insulators, mounting hardware and clamps shall be utilized to both insulate and support the busbars and cable so that they can withstand both normal and fault conditions.

16.3 Each phase of the AC input terminals shall be sized for the maximum rated input current. The AC cable input terminals shall be made of copper. The AC terminals shall be phased A-B-C, for each input set, from left to right facing into the AC input compartment door and shall be clearly labeled. The AC input terminals must meet the high potential test of section 17.5.4.

16.4 The DC output terminals shall be made of copper and shall be sized to handle the maximum output current of the rectifier module. The terminals shall be 3/8-16 threaded studs and shall be clearly labeled. Both terminals shall be ungrounded. The DC output terminals must meet the high potential test of section 17.5.4.

16.5 An isolating resistor shall be connected in series with the positive DC output terminal. The resistor value shall be 15 ohms and shall be sized to handle the maximum output current on a continuous duty basis. The resistor must meet the high potential test of section 17.5.4.

16.6 All low level control wiring shall be a type AMW appliance wire with 600 volt, 90 °C, stranded copper conductor or approved equal. The use of asbestos or teflon wire will not be acceptable. All wires shall be labeled for circuit identification at all termination points. All wiring must have an adequate voltage classification and be capable of meeting the high potential test of section 17.5.4.

16.7 All unused (spare) input and output (analog and control) channels of the PLC modules shall be wired to the module control compartment main terminal strip for use by Brookhaven. The vendor shall provide an additional twenty (20) spare terminals in the module control compartment for use by Brookhaven.

17.0 TESTING

17.1 The vendor shall provide the facilities and instrumentation at his plant to perform all necessary tests on each unit to assure compliance with all parts of this specification. Based on prototype testing, Brookhaven also reserves the right to require additional or more extensive tests to be conducted. The vendor shall provide seven (7) working days notice in advance of the test date so that Brookhaven can make the necessary travel arrangements. The testing shall include but not be limited to the specific tests outlined below.

17.2 Brookhaven requires prototype approval of a completely assembled rectifier module (first article) before substantial fabrication of subsequent modules shall proceed. Formal approval of some subassemblies may be granted by the Cognizant Engineer prior to prototype approval to help maintain delivery schedules. Brookhaven shall approve a prototype and individual component test results before substantial fabrication or procurement of parts of subsequent units shall proceed.

17.3 All test data shall be recorded and compiled in an individual test report for each rectifier module and shall be uniquely identified by the rectifier module serial number.

17.4 First Article Acceptance Test.

17.4.1 A heat run as defined in section 17.5.2 and the tests of section 17.5 shall be performed on the first article (prototype) rectifier module and shall be witnessed by BNL to insure compliance with the specification and the bid document. Upon successful completion of the first article acceptance test, BNL shall provide a written approval and a release for the remaining production units. The remaining units shall then be tested in accordance with the tests in section 17.5.

17.4.2 The factory heat run shall be performed to determine that the rectifier module meets the specified temperature rise of all major module components. Based on the test results of the prototype rectifier module BNL reserves the right to require that a heat run be performed on any or all of the subsequent units manufactured.

17.4.3 The thermal ratings shall be checked on each rectifier cell based on maximum operating current, when mounted in its final heatsink and with specified air flow and temperature. The case temperature, current and air flow shall be recorded, under stabilized conditions.

17.5 Acceptance Tests For All Rectifier Modules.

17.5.1 Air flow measurement shall be recorded on all subsequent units and the readings shall be compared to those of the prototype in lieu of heat runs.

17.5.2 Each fully assembled rectifier module shall be run to full rated voltage under lightly loaded conditions greater than 5% of full load current. Also, it shall be run at full output current and reduced output voltage.

17.5.3 All interlock protection and alarm indication circuits shall be checked for proper operation. Actual fault conditions shall be induced where possible.

17.5.4 On fully assembled modules, the following high potential tests shall be performed at 60 Hz for one (1) minute. Actual leakage currents shall be measured and recorded.

17.5.4.1 AC input terminals to frame .....35 KV rms

17.5.4.2 DC output terminals to frame .....35KV rms

17.5.4.3 Low voltage control and indication circuits to frame .....600 V rms

During the high potential tests, the interlock circuit, control circuits and PLC shall be grounded.

18.0 FINAL ACCEPTANCE

18.1 For purpose of warranty under an order for these rectifier modules, final acceptance is defined as successful completion of acceptance tests at BNL to substantiate compliance with the specification. The vendor will be notified of the test date at BNL and may have a representative present to witness the tests.

18.2 Final acceptance test at BNL will be performed within 90 days after delivery at BNL.

19.0 DOCUMENTATION

19.1 Upon delivery of the first rectifier module three (3) sets of as built, signed, final prints shall be supplied by the vendor. These prints shall be made to the highest professional drafting standards. Computer CAD system drawing plots must also be provided on CD or DVD. If it is not in the format of "AutoCAD" or "PCAD" drawing files, the format must be approved by BNL.

19.2 Before delivery of the final rectifier module five (5) copies of the final parts list, including suppliers, shall be provided by the vendor. This shall list all components used in the fabrication of the rectifiers, identifying those parts recommended by the vendor as required spare parts to insure efficient, reliable operation. These shall also be included on the documentation CD or DVD.

19.3 The information required under paragraphs 19.1 and 19.2 as well as all test results, technical descriptions, data sheets on gauges, meters, valves and other pertinent

components shall be supplied in bound design and operations manuals. Three copies of this manual shall be supplied for each series of rectifier modules at the time of delivery of the last rectifier. This documention shall also be included on the documentation CD or DVD.

20.0 QUALITY ASSURANCE

20.1 The Vendor shall furnish a manufacturing plan and acceptance test procedures for approval by Brookhaven. Approval by Brookhaven shall not release the Vendor from his responsibility for conceptual design, manufacturing, or any other mistakes committed in the fabrication of the rectifier module.

20.2 All purchased articles from subcontractors or manufacturers released for inclusion in this power supply shall be clearly identified to indicate conformance to Vendor's receiving inspection.

20.3 All elements of this equipment shall be covered by a guarantee against material and manufacturing faults. The Vendor shall specify in detail the guarantee period and its provisions in his proposal. The guarantee period shall be for a period of at least two (2) calendar years from the final acceptance test date.

20.4 These quality assurance requirements are in addition to the following quality assurance requirements, which will be found in Brookhaven document BNL-QA-101, attached to the purchase order. The following sections apply: 1, 2, 3, 3.1.2, 4.1, 4.3, 4.4, 4.4.2, 4.5, 4.6, 4.7, 4.7.1, 4.10, 4.10.1, 4.10.2, 4.10.3, 4.13, 4.16, 4.18, 4.18.1, 4.19 and 4.21.

20.5 Traveler sheets shall follow each piece of equipment through production. These sheets shall document critical processes and settings for each article and shall serve as a history of its production. Copies of these travelers shall be supplied to Brookhaven.

20.6 Only calibrated test equipment shall be used. Copies of the test data sheets shall include lists of the instruments used to perform the tests and the calibration due date of each instrument.

20.7 The Vendor shall establish those controls and processes necessary to ensure uniformity of all deliverable articles. All controls, inspections, tests and quality provisions established during development and pre-production tests shall be indicated on the applicable drawing and shall be performed on each deliverable article.

20.8 All units and parts of the equipment shall be properly packaged and delivered in an undamaged condition to BNL. The seller shall ship all equipment via air ride trucks. Devices shall be installed on the equipment during shipment, which will record any unusual mechanical shocks

21.0 VENDOR DATA SHEET

21.1 Main rectifier bridge:

Manufacturer and Type....._____

Peak inverse voltage ....._____

Forward current, It(avg)....._____

Peak one-cycle on-state current, Item....._____

21.2 Filter choke:

Inductance, Hy ....._____

DC resistance ....._____

Manufacturer....._____

Insulation class....._____

Expected temperature rise....._____

21.3 Filter capacitor:

Capacitance....._____

Voltage rating ....._____

Joules ....._____

Discharge life, crowbar pulses....._____

Manufacturer and type ....._____

Fluid type ....._____

21.4 Filter damping:

Description....._____

Resistance ....._____

21.5 Crowbar:

Ignitron manufacturer and type....._____

Ignitron voltage rating ....._____

Current ratings ....._____

Pulse transformer manufacturer....._____

Transformer type....._____

Primary Voltage....._____

Secondary voltage, each winding ....._____

Isolation voltage....._____

Transformer input impedance....._____

Rise time ....._____

21.6 AC input transient suppressor:

Manufacturer and type....._____

Voltage limit value (max)....._____

Power rating, joules ....._____

21.7 DC over current relay:

Manufacturer and type....._____

21.8 DC current transducer, DCCT:

Manufacturer and type....._____

Output voltage at maximum current ....._____

Current rating....._____

Frequency response....._____

Accuracy ....._____

21.9 DC voltage transducer, DCPT:

Manufacturer and type ....._____

Input voltage range ....._____

Input resistor, ohms and watts ....._____

21.10 Module estimated dimensions:

Front width....._____

Depth....._____

Height....._____

Weight....._____

21.11 Output resistance:

Ohms....._____

Watts ....._____

22.0 Simplified schematic diagram.

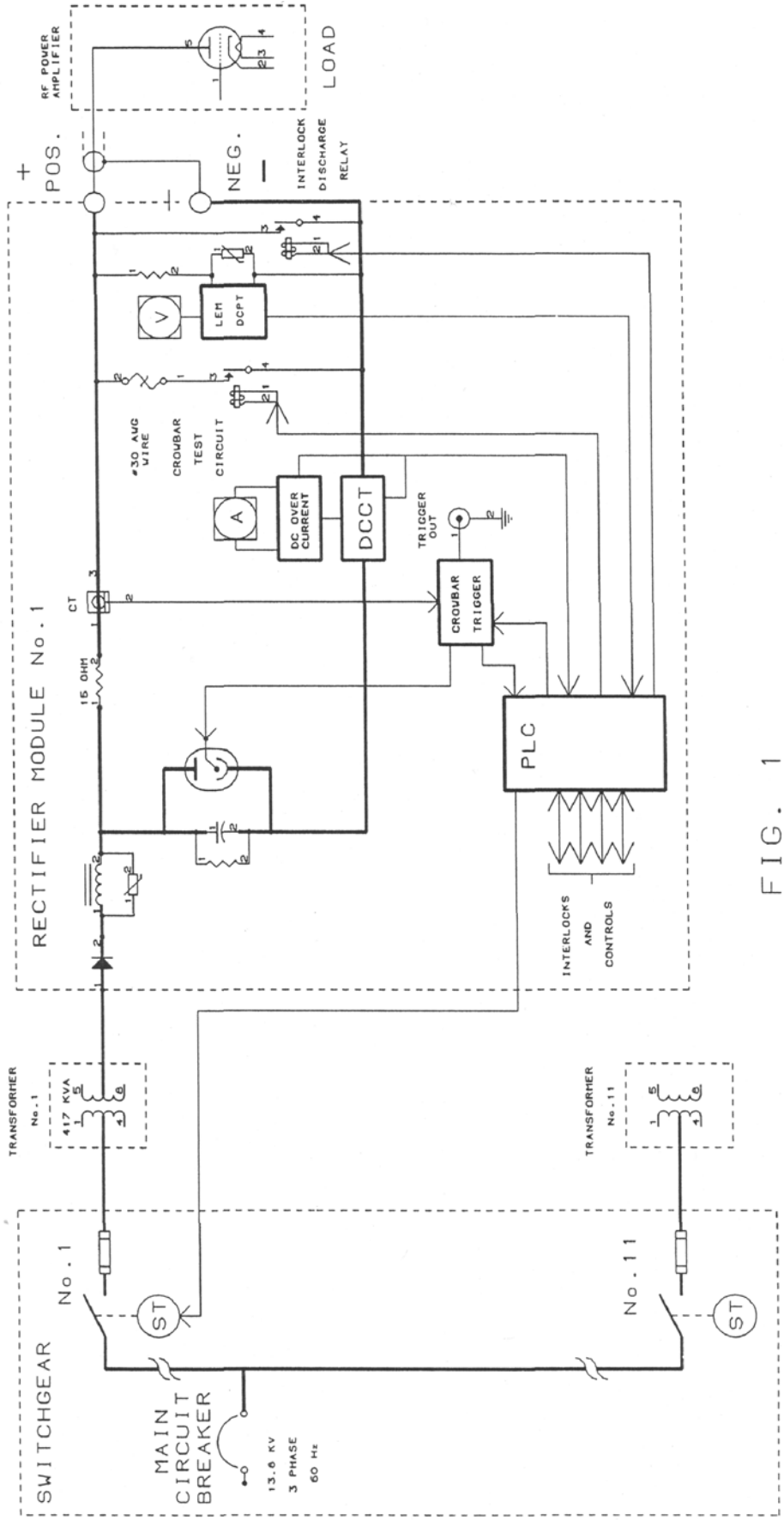

FIG. 1

23.0 Physical Configuration

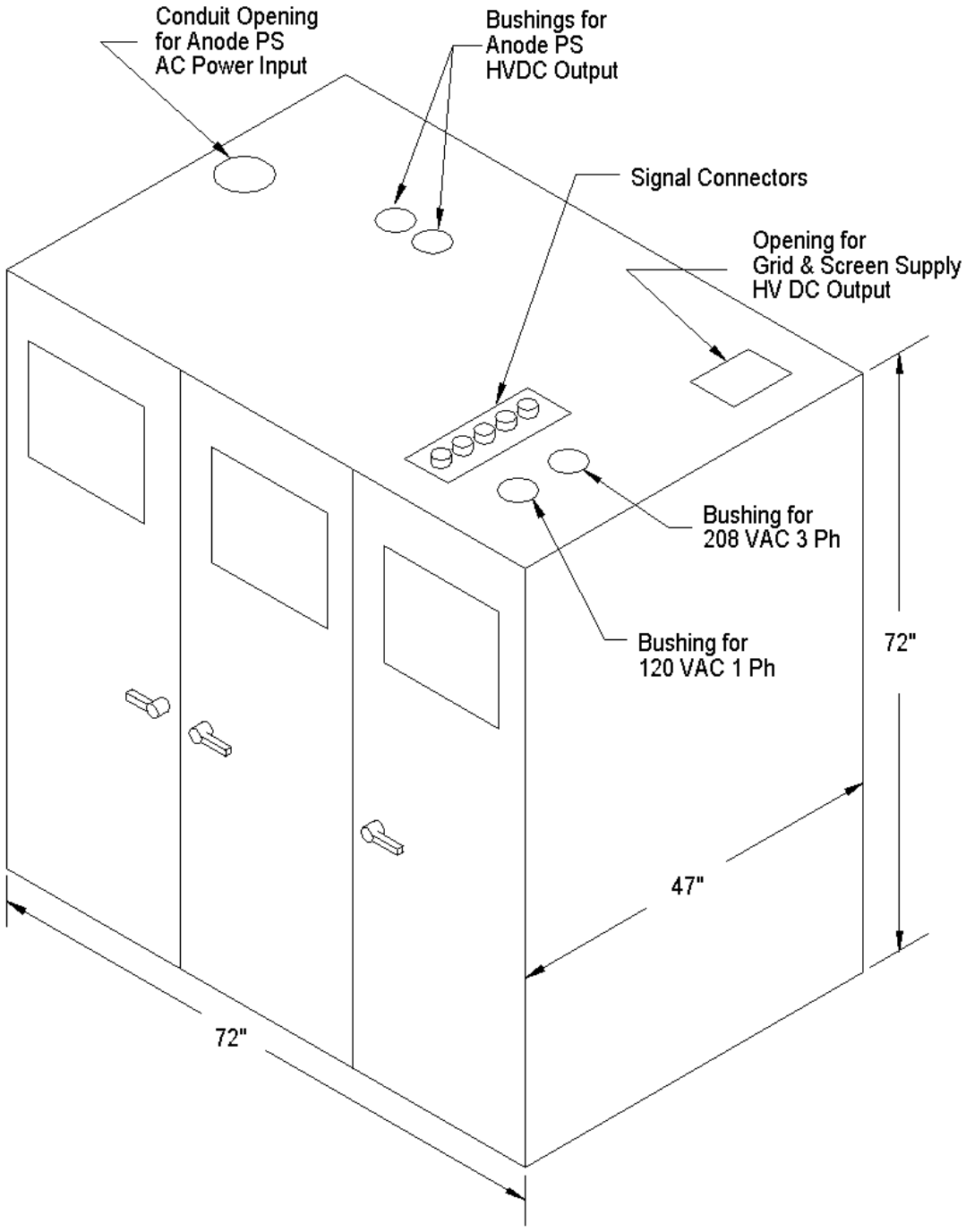

Figure 2. Physical Arrangement